PRIVATE AND CONFIDENTIAL

RESEARCH DEPARTMENT

VISITS TO THE F.C.C., THE ZENITH CORPORATION AND BELL TELEPHONE LABORATORIES, U.S.A., MARCH 1962

Report No. A-068

(1962/15)

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

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Section Title Page

1 INTRODUCTION 1

2 DISCUSSIONS WITH THE F.C.C. 1

2.1. U.H.F. Field Tests 1
2.2. Stereophonic Broadcasting 2

3 VISIT TO ZENITH CORPORATION, CHICAGO 3

3.1. Transmitting Techniques with Stereophonic Broadcasting 3
3.2. Receivers for Stereophonic Broadcasting 4
3.3. Colour Television Receivers 5

4 VISIT TO BELL TELEPHONE LABORATORIES, MURRAY HILL 5

4.1. Stereophonic Broadcasting 6
4.2. Special Techniques for Stereophony 6
4.3. Public Address System with Frequency Shift 6
4.4. 'Vocoder' Techniques 7
4.5. Compatible Single Sideband Transmission 7

5 REFERENCES 7

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1. INTRODUCTION

After attending the C.C.I.R. Study Group IV meetings in Washington, March 12th–23rd, the author joined in discussions with the Federal Communications Commission on the afternoon of 23rd March at which Sir Harold Bishop and Mr. E.W. Hayes, representing the B.B.C., met the Chief Engineer of the F.C.C. and other members of his staff. The author then arranged a visit to the Zenith Radio Corporation, Chicago, on March 26th and a visit to the Bell Telephone Laboratories at Murray Hill on March 27th. The principal interest of the author was the progress in stereophonic broadcasting in the U.S.A. but some information was also gained on u.h.f. television transmissions and on other items of general interest.

2. DISCUSSIONS WITH THE F.C.C.

2.1. U.H.F. Field Tests

During the discussions with the F.C.C., the representatives met besides Mr. E.W. Allen the Chief Engineer were Messrs. Renton, Scrivseth, Richardson and Kassens. The main topic was the preliminary results of the tests being undertaken by the F.C.C. in New York on reception of u.h.f. transmissions WUHF from the Empire State Building. An interim report on the tests was due to be presented by Mr. Allen to the National Association of Broadcasting Engineers Conference to be held in Chicago at the beginning of April, but copies of this interim report had already been made available to the B.B.C.

The primary purpose of the tests was not to examine the extent of a u.h.f. service area but to examine the quality of service that a u.h.f. transmitter could give in a built-up area with many tall buildings, and to compare the performance with that obtained on the lower television bands in the same area. To this end, observations under domestic conditions are being confined within a radius of 25 miles from the transmitter. However, the F.C.C. is also making observations with mobile receivers on a number of radials and in this case the quality of reception is being examined at all distances from the transmitter up to the limit of satisfactory reception; on some of the radials observations are being made up to a distance of about 80 miles.

One important series of tests already undertaken was on the performance with circularly-polarized transmissions. In order to facilitate a reliable comparison with horizontal polarization, the transmitting aerial used consisted of a metallic horn with square cross-section which could be excited by two separate feed elements giving two mutually perpendicular linear polarizations. For horizontal polarization the feeds are co-phased while for circular polarization the phase of one feed is changed by 90°. This aerial was capable of covering one sector only because of its horizontal directivity. The aerial gain was about 14 dB in each condition and, when fed by the 50 kW transmitter, gave an effective radiated power (e.r.p.) in excess of 1 megawatt. For receiving, a helical aerial was used for the circularly-polarized transmissions and a bow-tie dipole in a corner reflector for the horizontally-polarized transmissions. From the measurements that had been made, both with a mobile truck and at sample locations, very little difference was observed on the average between the two forms of polarization. A possible advantage for circular polarization was obtained only at very low field strengths, but the effect was slight and based on a few measurements only. It appeared clear from evidence already obtained that any advantage of circular polarization would be very small.

In a second phase of the experiments an omnidirectional aerial for horizontal polarization was used, consisting of four panels in a skew-fire arrangement, giving a relatively smooth omnidirectional pattern with maxima and minima within ± 5 dB of the average value. The mean e.r.p. was 850 kW. The preliminary results have shown a surprising similarity between the percentage of sites obtaining a satisfactory picture at u.h.f. (Channel 31) and the corresponding percentages for the high v.h.f. band (Band III, Channel 7) and the low v.h.f. band (Band I, Channel 2). This situation was true both in the series of measurements in which indoor aerials were used and in those using roof-top aerials; the latter aerials were typical types of moderate size appropriate to each Band. The percentages decreased slightly with increasing frequency but there appeared to be no greater difference between u.h.f. and Band III than between Bands III and I.

During the discussion Mr. Allen mentioned that the field strengths of 74 dB (μV/m) and 64 dB (μV/m), which had been considered necessary for Grade A and Grade B services respectively when u.h.f. stations were first started, had been based on a receiver noise factor of 15 dB. He now considered that a noise factor of about 10 dB could be taken for the latest receivers in the U.S.A. Regarding local variations of field strength from a u.h.f. transmitter, it was stated that a total range of variation of about 10 dB was typical for a 100 ft-run with the mobile receiving aerial, although there were sometimes deeper drops in the field strength. Regarding the question of the quality of the picture in those cases where it was necessary to orient the aerial on a strong reflexion rather than the direct signal, it appeared that insufficient cases of this had been observed so far, but the feeling that the picture quality would not be very good in these circumstances was expressed.

2.2. Stereophonic Broadcasting

Mr. Kassens felt that f.m. stereophonic broadcasting has a good future in the U.S.A. The standards for the Zenith-G.E. system as used in the U.S.A. were given in the F.C.C. Report and Order of April 20, 1961, and have been summarized elsewhere.[1] It is relatively easy for stations to equip themselves for stereophonic broadcasting, and transmitters for all new installations are of a design suitable for taking stereophonic programmes. This did not necessarily mean that all new f.m. transmitters are fully equipped with the stereophonic coder but that the design is such that relatively simple and cheap additions can be made when required to complete the installation for stereophonic broadcasting. Out of a total of 1100 f.m. stations in the U.S.A., 72 stations were already equipped for stereophonic broadcasting by

March 1962. When asked if the major limitation on service areas in the U.S.A. was interference from other transmissions, Mr. Kassens replied that probably the majority of stations were interference-limited in their service area rather than field-strength limited, but he pointed out that the distribution of stations was far from uniform and, on the basis of area, the limitation would not be due to interference in most of the U.S.A.

As mentioned later (Section 4.1), serious consideration has not been given to the problem of long-distance links for stereophonic programmes, and the broadcast material consists mainly of commercial disk and tape recordings reproduced on an individual basis at each station.

3. VISIT TO ZENITH CORPORATION, CHICAGO

During the visit to the Zenith Corporation, Chicago, information was supplied both on the subject of stereophonic broadcasting and on television receiving techniques by Mr. Carl G. Eilers.

3.1. Transmitting Techniques with Stereophonic Broadcasting

In Chicago three stations, namely WEFM, WKFM and WFMT, were operating with stereophonic transmissions, the first two starting in June 1961 and the latter at the beginning of 1962. The first of these stations is owned and operated by the Zenith Corporation and transmits in addition a "storecasting" programme on a 67 kc/s f.m. subcarrier according to the standard laid down for Subsidiary Communications Authorization (S.C.A.). In this case, considerable extra care has to be exercised in the design of the equipment to avoid non-linearities. For example, if all modulating signals are fed directly into the transmitter, the harmonics of frequencies near 38 kc/s must be removed by a low-pass filter. This, in turn, may introduce unwanted phase shifts in the sidebands of the stereophonic subcarrier unless a good design of phase-corrected low-pass filter is employed. In an effort to simplify the filter requirements, Zenith have taken an alternative approach in the design of the transmitting equipment which involves a number of frequency changes, although on balance it did not appear that this approach would necessarily be the most economical. Regarding the performance of stereophonic transmitting equipment in the U.S.A., Mr. Eilers said that there had been some complaints of interference from S.C.A. transmissions to stereophonic reception which, in the case of some stations, could be traced to defects at the transmitter, but their own station had managed to avoid this difficulty. There were also instances of similar effects which could be attributed to poor receivers.

One important parameter of the Zenith-G.E. system, for which a tolerance has not yet been given in the F.C.C. regulations, is the phase difference between the 19 kc/s pilot signal and the virtual 38 kc/s subcarrier signal. Zenith had recommended that the F.C.C. specified a tolerance of $\pm 3^\circ$ for the 19 kc/s pilot phase relative to the ideal phase. This ideal phase requires that in the multiplex waveform with modulation in the left channel only, taking the components of the waveform separately, the zero crossings of the 19 kc/s signal should coincide with upward crossings of the 38 kc/s subcarrier signal when the modulating signal is of positive polarity. Although the phase can be made approximately correct by proper design of the equipment, it is not easy to check the exact phase at the transmitter for the purpose of fine adjustment. The Zenith laboratories had designed a unit which would be capable of checking this parameter during the course of stereophonic transmissions. It takes the form of an amplitude demodulator operating with a restored carrier derived from the 19 kc/s pilot but shifted 90° in phase from that normally used in a stereophonic receiver. The phase of the pilot carrier on the transmitter can be adjusted, on programme, for a minimum output from this unit; the accuracy of the test unit may be checked internally at any time by the use of a wave-form derived from square-wave generators, in which the phase relationship of the 19 kc/s and 38 kc/s components is basically accurate.

3.2. Receivers for Stereophonic Broadcasting

In the original tests the Zenith Corporation had employed stereophonic adapters in which a beam-switching tube was used to demodulate the a.m. subcarrier. However, the range of commercial receivers now being sold did not employ this method because it was considered that it would put up the cost of the equipment unnecessarily. Instead, a design using simple diode detectors had been successfully produced and formed the basis of their equipment, from small table stereophonic receivers to the large radio-gramophone combination receivers. A small table receiver had been introduced to give, by switch selection, either the left-hand signal or the right-hand signal and it was intended for use in conjunction with a conventional receiver which would produce the sum of the left and right signals. The stereophonic "width" thus produced would, of course, be halved as compared with normal use of the two loudspeakers since the source of sound would appear to come from positions ranging from mid-way between the two speakers up to the speaker of the conventional receiver. A good-class general-purpose stereophonic receiver had now been introduced. This model, the MJ 1035, consisted of a table model a.m./f.m. receiver of reasonable size and a separate table cabinet with a second loudspeaker which could be spaced from the main receiver according to listening requirements. The speakers reproduced the left and right signals in the usual way, and when demonstrated appeared to give good results, considering the size of the cabinets.

One of the subjects discussed was the relative merits of achieving the de-emphasis of the subcarrier signal before or after the subcarrier detector. In the former case a single tuned circuit of the appropriate bandwidth is placed in front of the detector and so adjusted in bandwidth that de-emphasis is achieved by sideband attenuation. From experience in Europe this method had appeared to give less adjacent-channel interference than when de-emphasis is carried out at audio frequency in the conventional way. Mr. Eilers pointed out two disadvantages of de-emphasis before detection, the first being the increased difficulty of filtering the "switching" or restored-carrier components so that the audio-frequency stages would not be affected. The second disadvantage, applicable only where storecasting might be used, was that the 67 kc/s trap circuit, which is essential to avoid interference from the S.C.A. transmission, may introduce phase shifts and complicate the design and operation of a pre-detector de-emphasis circuit. However, he thought that for Europe (where the latter disadvantage did not apply) this technique would be a good one. On the subject of impulsive interference, Mr. Eilers said that the experience in the U.S. had been that the f.m. subcarrier systems tend to be more susceptible than the a.m. subcarrier systems. On the question of interference from other stations, the Zenith Corporation had made some laboratory tests which were in good agreement with those made in Europe. However, there was some difficulty in reconciling the objective and subjective tests on co-channel interference which had suggested extra protection ratios of 24 dB and 6 to 8 dB respectively. B.B.C. experience in the past has been that the objective tests on co-channel interference have never given a satisfactory indication of interference experienced in the case of monophonic f.m. transmissions. The large value obtained by the objective method for the degredation of co-channel interference in stereophonic reception, which was viewed with some concern by Mr. Eilers, is undoubtedly pessimistic.

3.3. Colour Television Receivers

The Zenith Corporation has now entered the market for colour television receivers and has been producing receivers for over a year. It appears that they are able to sell all the receivers that they can produce at the present time but a note of the production figures was not taken. In regard to the design of colour receivers, one feature of the Zenith receiver is the use of two 6JH8 beam-switching tubes for the B-Y and R-Y colour demodulators. The R.C.A. three-gun colour-dot tube is employed.

In the course of discussion Mr. Eilers gave the requirements he considered necessary in the pre-detector frequency response. As with other makes of colour receiver, two separate detectors are used, one solely for obtaining the inter-carrier frequency for the sound channel and the other for providing the picture signal (luminance and chrominance). In the former case the response at the sound carrier frequency would be -20 dB relative to the picture carrier (-26 dB relative to peak response) while in the latter detector the corresponding figure would be at least 30 dB relative to picture carrier (-36 dB relative to peak response). In the Zenith colour receiver the sound carrier (41·25 Mc/s intermediate frequency) is brought down to the -20 dB level at the coupling between the mixer stage of the tuner unit and the first i.f. amplifier. The coupling from the anode of the third (final) i.f. stage to the detector for the picture signal includes a transformer and a 41·25 Mc/s tuned circuit of the balancing type which is provided with a pre-set "null adjustment resistor". This might well, if carefully adjusted, provide an overall pre-detector rejection higher than the -30 dB figure given by Mr. Eilers. The sound discriminator, which follows the first sound detector and 4·5 Mc/s amplifier and limiter, uses the "quadrature grid" method as employed widely in black-and-white receivers in the U.S.A.

When questioned on the value of the group-delay pre-emphasis characteristic standardized by the F.C.C. for colour transmissions, Mr. Eilers considered that the correction was relatively small in relation to the characteristics of receivers bearing in mind that, even in colour receivers, it was usual to have a frequency response at the vision detector which was 4 to 6 dB below peak response at the colour subcarrier frequency. The figures discussed above for the sound carrier attenuation required were based on the assumption of this response at the colour subcarrier frequency.

4. VISIT TO BELL TELEPHONE LABORATORIES, MURRAY HILL

During the visit to Murray Hill a number of items of interest on which Dr. M.R. Schroeder was working were discussed besides the various aspects of stereophony on which he and Mr. F.K. Harvey have been working.

4.1. Stereophonic Broadcasting

One of the questions of interest to the B.B.C. is the line transmission of stereophonic programmes over long distances, as would be required in the case of a national network. During discussions on this subject with Mr. Harvey and Mr. J.M. Barstow, it appeared that the Bell Laboratories had asked the broadcasting concerns if there were likely to be a requirement for long-distance stereophonic networking, but there was no demand or interest in this at the present time, so development work on this subject was not going ahead. Mr. Barstow thought that the most practical method of long-distance transmission over carrier circuits would be to modulate the two stereophonic signals on to the same carrier frequency using the quadrature modulation principle, i.e., modulation of an "in-phase" carrier for the left-hand signal and modulation of a "quadrature-phase" carrier for the right-hand signal. As regards existing requirements, there were several cases where the American Telephone and Telegraph Company had provided short links on pairs of ordinary telephone lines between studio premises and the f.m. transmitter, over distances of the order of ten miles. For this purpose the lines were matched for equality of time-delay to about 10 μs in order that the frequency response of the sum of the left- and right-hand signals should be uniform to 2 dB.

4.2. Special Techniques for Stereophony

Work was in progress on artificial methods of producing stereophonic effects. One of the effects is stereophonic reverberation, which has been described in the literature.[2] A tape recording was heard giving an example of a monophonic recording of organ music to which stereophonic artificial reverberation had been added. An IBM 7090 digital computer had processed the tape to simulate one of the methods proposed by Schroeder, namely the use of all-pass networks in tandem, each of which has an impulse response consisting of a decaying series of impulses.

Another more recent investigation had been into the processing of a tape recording (monophonic) in a computer to produce a stereophonic recording which, on play-back, would give an image at a position not between the two loudspeakers but outside this range, for example on the extreme left of a listener as he faces a central position between the two loudspeakers. The process takes into account the various paths between the loudspeakers and the ears and produces cancelling signals where required in order to simulate as closely as possible the effect on the ears that would be given by a source of sound in the required position. An example was heard of short excerpts of speech. Provided that the listener was in a central listening position and facing forward, the illusion of sounds originating in positions up to 90° on one side was extremely effective. However, on moving appreciably from the central position, a source initially appearing to come from the extreme left would appear to move over to the position of the left-hand loudspeaker. Similarly, if the listener remained in the central position but turned his head to face the apparent source of sound, the illusion would once again fail and the sound would appear to come from the left-hand loudspeaker.

4.3. Public Address System with Frequency Shift

The method of decreasing the feedback in public address systems by a small frequency shift of the microphone signal, e.g. by 5 c/s, was described at the Third

International Congress on Acoustics in 1959.[3] An amplifier based on this principle was now being manufactured in the U.S.A. by H.A. Roseberry and Son, Michigan, the cost being of the order of $500. Dr. Schroeder thought that the price might be reduced in the near future. The equipment at present being manufactured is called "Model 8961 Feed-Bak Stabilizer".

4.4. 'Vocoder' Techniques

A development for which Dr. Schroeder has been responsible and which is likely to find important applications in future, is the saving of bandwidth in telephone systems by the use of 'Vocoder' techniques. In the past, development has tended to aim at a very large bandwidth saving factor (of the order of ten) but the resulting speech has been very far from natural. Dr. Schroeder has approached the problem from the other direction by aiming initially at a bandwidth saving of only two to one. Unlike the original 'Vocoder', the frequency of the voice tone is not coded but is sent directly over the circuit. However, the vowels and consonants are coded and at the receiving end a speech tone rich in harmonics is generated from the voice frequency. The spectrum is then modified by control from the coded signals to produce the correct speech sound. On hearing the demonstration of this system it is difficult to detect any difference from the original (when the latter is already reduced to current telephone quality) and there is no doubt that processed signal is as intelligible as the original.

In a further development Dr. Schroeder is experimenting with a "correlation" coder by which he hopes to achieve good results with a bandwidth reduction factor of four. The advantage of the new method is that it avoids the need for a large number of filters. The success of the technique is at present being examined by simulating the necessary circuits and processing on a digital computer, thus establishing the optimum arrangement without actually building any experimental equipment.

4.5. Compatible Single Sideband Transmission

A paper by B.F. Logan and M.R. Schroeder on compatible single sideband transmission has been prepared for the Brussels Symposium on Information Theory being held early in September 1962. This is a purely theoretical study which makes a different approach from that of Kahn and shows the conditions that have to be fulfilled in order to produce an envelope of the required form by means of a signal consisting of a carrier and sidebands confined to one side only of the carrier frequency.

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3. Schroeder, M.R., "Improvement of Acoustic Feedback Stability in Public Address Systems", Proceedings of the Third International Congress on Acoustics, Elsevier Publishing Company Amsterdam, 1960, p.771.
(See "Visit to Germany - September 1959", Research Department Report No. A-057, Serial No. 1960/2, Section 2.2.9.)

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